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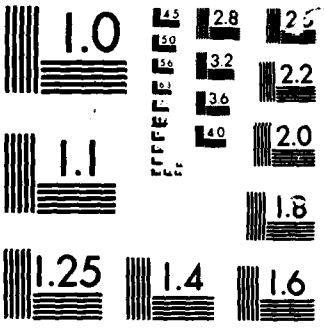

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A SYSTEM FOR CONTROLLED PRESENTATION OF THE ARDEN CONTRAST SENSITIVITY TEST

U S ARMY RESEARCH INSTITUTE
OF
ENVIRONMENTAL MEDICINE
Natick, Massachusetts

DECEMBER 1985

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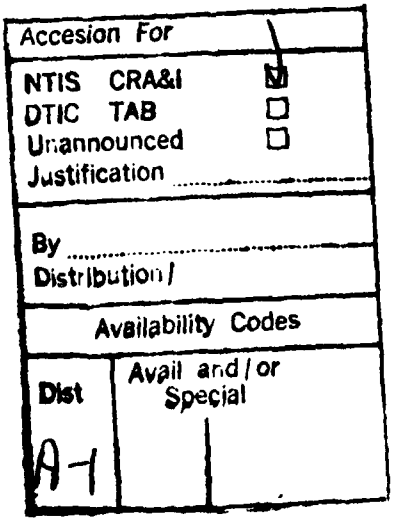

A System for Controlled Presentation of the Arden Contrast Sensitivity Test

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ABSTRACT

Contrast sensitivity has been identified as a significant index of visual function ,and as an indicator of visual disorders. The Arden test of contrast sensitivity has been recognized as a simple and easily administered technique for measurement of this process. However, this test is involves manual manipulation and considerable individual subjectivity. The instrument described in this report was designed and developed to eliminate variability in the testing procedure due to differences in individual testing techniques, and to standardize testing conditions, ambient illumination, viewing distance and rates of presentation.

INTRODUCTION

The detection of differences in brightness, also called contrast sensitivity, has been increasingly recognized in recent years as a visual phenomenon of potentially great significance both for explaining the visual perception process and for diagnosing visual disorders. The contrast sensitivity function (CSF) is generally considered to be based mainly on the physiological phenomenon of bleaching of cone pigments and associated neural relationships in the retina. In effect, if the foreground of a display is darker than the background, then the cone pigments involved in central fixation are bleached less than those of the paracentral areas. The limiting physical parameters within which this function can occur are determined by the characteristics of the prevailing field of view.

The virtually infinite variety of spatial configuration contained in the viewing field generates frequencies and contrasts which vary from moment to moment. In terms of this fluctuating array, the visual world can be conceptualized as an ever-changing configuration of objects composed of brightness contrast relationships, in which the variable array triggers the contrast sensitivity response. Although the term "detail" involves high frequencies only, the term "texture" involves the manner of union of the particles comprising an object, and thus does not alter the visual angle subtended by that object. However, changing the configuration of an object will affect the visual angle and the spatial frequencies involved.

The CSF can provide information about the status of the human visual system which cannot be obtained from visual acuity measurements. For example, in a low contrast viewing situation such as a dimly illuminated scene, the fine details of a target object become indiscernible. At the same time, however, low spatial frequencies emitted by such a view stimulate para-foveal retinal areas to provide cues for determining the presence of or detecting object outlines and aspects of figure-ground separation. While identification is a function of high frequencies and good contrast, gross recognition without identification, such as detecting an island in the fog, is a function related to low frequencies. The perception of poorly-lit objects depends largely on information delivered by the para-foveal retina sensitive to low spatial frequencies generated by global outlines. Visual acuity measurements could not reflect such performance, since this function is largely foveal, and as such is inoperative at low illumination levels.

As objects become progressively illuminated, their early detection still remains a function of the para-foveal region of the retina. However, as illumination increases to still higher levels, recognition of detail shifts to a dependence on retinal physiological processes triggered by higher spatial frequencies stimulating the fovea.

The ability to resolve visual detail is embodied in a number of visual indices, the most familiar of which is probably visual acuity as measured with a Snellen chart. It is interesting to note that in a recent study of aircraft detection and identification, a strong relationship was found between ability to detect targets and sensitivity for the lower spatial frequencies among individuals (Ginsburg,1981). This suggests that contrast sensitivity may be superior to visual acuity as an overall indicator of effective target detection.

During the last decade, measurement of the CSF has gained interest among many researchers. However, it is still only rarely used as a diagnostic tool in the ophthalmic office (Comerford,1979). Nevertheless, evidence of its usefulness continues to gain greater notice, and if this trend continues the CSF may eventually become a routine diagnostic test. It has already been documented as an effective means of diagnosing cataract (Hess and Woo,1978); glaucoma (Atkin, et al,1979); amblyopia (Hess,1979); retinal degeneration (Woo and Long,1979); multiple sclerosis (Regan, et al,1977); other ocular diseases (Arden and Gucukoglu,1978; Bodis-Wallner,1972); and, physical changes due to contact lens wear (Applegate and Massof, 1975).

Despite its significance as an indicator of ocular pathology, the effects of exposure to environmental and other stressors on the CSF in normal individuals has not yet been established. However, research by Ginsburg for the Air Force (ibid, 1981) suggests that the CSF may indeed be useful in this connection.

One of the recent techniques developed for measurement of visual contrast sensitivity is the Arden test described in 1978 (Arden,1978), and introduced commercially by the American Optical Company in 1981. This test is based on the principle attributed to Newton and Fourier that any complex wave-form can be separated into individual sinusoidal components of frequency and amplitude (Fourier transformation). This principle was later employed by Mach (1886) to develop elemental sine-wave gratings, which were later quantified and calibrated (Campbell and Green, 1965; Campbell and Robson, 1964, 1968). The Arden test consists of six sine-wave gratings of this type selected to represent low, intermediate and moderately high frequencies of brightness alternation (0.2, 0.4, 0.8, 1.6, 3.2, 6.4 cycles per degree (c/d)). They are presented as a series of six 8 inch x 10 inch photographically printed plates. Each plate varies in frequency from top to bottom, along the 8 inch dimension, and appears as a series of light and dark undulating stripes according to the sine wave function represented at a given contrast in units of cycles per degree of visual angle. A graduated 25-interval scale is printed along the edge of the 8-inch dimension of each plate, and serves as a scoring measure of response to that plate. The numerical value on this scale at which the subject notes a change in brightness is used as an index score of his contrast sensitivity threshold.

The 6.4 c/d plate is the easiest to resolve, having a visual angle of approximately 6 arc-minutes for each bar. This grating is almost equivalent to the 20/100 letter of the Snellen chart (Snellen denominator = 600/spatial frequency), and images on the paracentral area of the retina. As the c/d values of the plates decrease, contrast sensitivity diminishes, and imaging shifts to an area covering 12^{o}-15^{o} of the peripheral macula. The theoretical threshold grid separation that can be distinguished is considered to be at least 1 minute, or 30 cycles per degree (c/d). Thus, any plate with more than 30 c/d will appear to be homogeneously gray. If this plate were available, it would measure foveal performance.

The conventional procedure for administering the Arden test is to present each plate individually to the subject with the 10 inch side positioned horizontally, beginning with the entire plate covered by a blank overlay plate of the same size. By a manual procedure, the tester then

slowly raises the top horizontal edge of the Arden plate above the overlay, so that the area of the plate is progressively revealed along its 8 inch dimension. This procedure is continued until the subject indicates that he can detect a cyclic change in brightness. The numerical value on the scale corresponding to this position on the plate is noted as the subject's threshold. The scale values obtained are then represented graphically as a plot of contrast sensitivity versus spatial frequency.

The simplicity of the Arden test is both lauded and criticized. While it is surprisingly easy to administer and requires a minimum of testing equipment, it is clearly deficient in testing controls. The rate of exposure of the test plates above the masking plate is determined manually by the tester, and can easily vary from plate to plate. Since the plates are hand-held, the viewing distance is determined by the tester's technique, and can also fluctuate over the course of the test. This could significantly alter the visual angles of the targets, and affect the subtended retinal areas involved. Ambient illumination of the plates and incident reflected glare are uncertain, and surely must be a highly variable factor among the situations in which the test can be used. All of these conditions are certain to be influenced by the skill, practice and concentration of the tester, and must be expected to vary widely among users. Finally, there is no control for distractions and interferences which may occur in the testing situation. Despite the limitations inherent in the current testing procedure, the Arden test offers a very simple method for measurement of CSF. Since this measure promises to reflect reactivity to numerous stress factors, both environmental and psychological, it could be of considerable significance as a practical measure of commonplace viewing. It also has a major advantage inherent in its simplicity. However, it would be significantly improved if the testing conditions were better standardized.

The instrument described in this paper was developed to provide a standardized method of administration of the Arden test which would avoid the variability inherent in manual presentation procedures used at the present time.

DESCRIPTION OF THE APPARATUS

The instrument described here consists basically of a rectangular housing (12"x12"x24") with a viewing position at one end, and the Arden plate presentation system at the other end. An illustration of the overall apparatus is shown as Figure 1; a schematic diagram of its functional arrangement is shown as Figure 2.

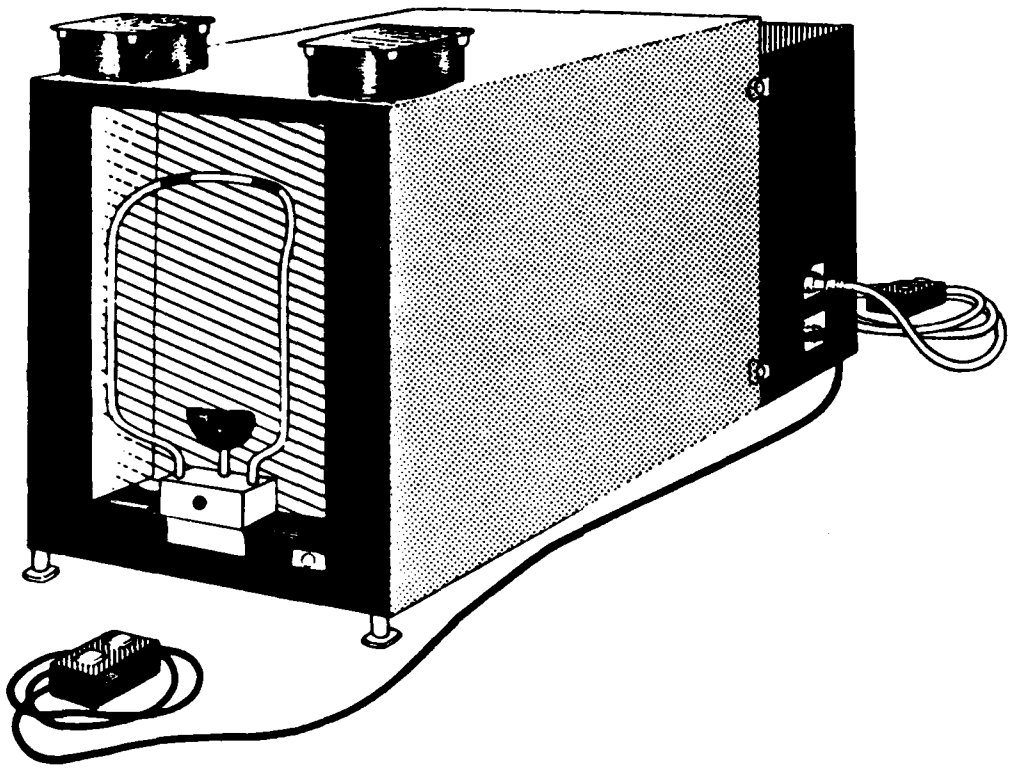

Figure 1. Sketch of the overall apparatus

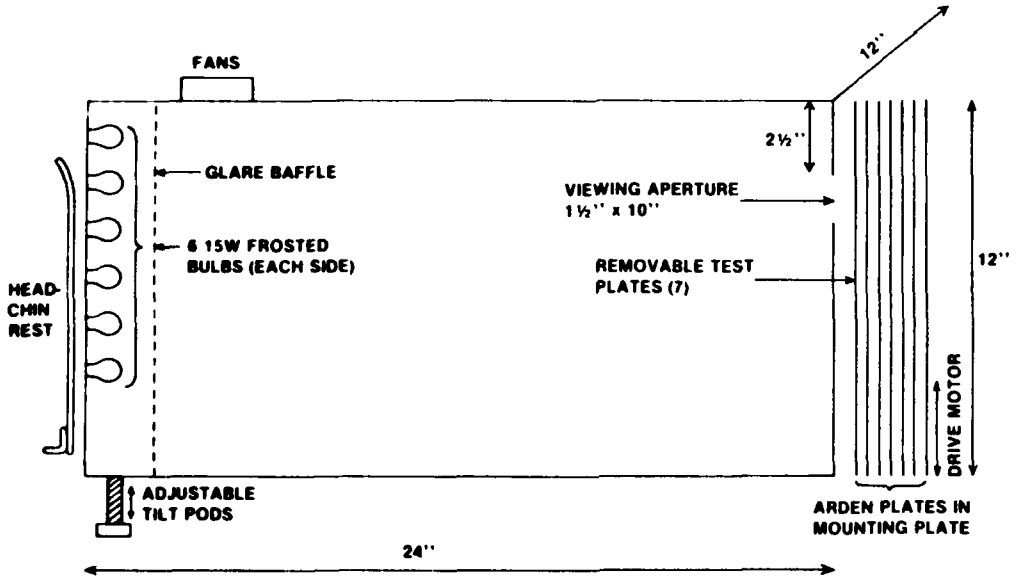

Figure 2. Schematic diagram of the apparatus configuration

The housing is open at one end, and a head and chin rest is mounted just exterior to this opening to stabilize the patient's line of sight in the viewing position. The entire interior of the housing is painted flat gray to minimize glare and reflections. Two baffles are installed along the vertical edges of the opening, and facing inward. Twelve 15-watt frosted incandescent bulbs are mounted at intervals behind the baffles (six bulbs on each side), so as to evenly illuminate the opposite end of the housing. The baffles act both to direct the illumination toward the far end of the housing, and to prevent glare in the patient's field of view.

The opposite end of the housing is a flat gray plate (12"x12") containing an aperture (1 1/2"x10") positioned horizontally and 2 1/2" below the top edge of the housing. A movable flat mounting plate (also 12"x12") is installed in vertical tracks directly behind the aperture plate. A reversible motor with an instant start-stop clutch is latched to the mounting plate through a variable-speed gear drive. By this arrangement, the mounting plate can be raised or lowered at a desired constant rate, and stops instantly when deactivated. A two-way switch controls the rate and direction of the motor, and thus, the vertical motion of the mounting plate.

The set of six Arden test plates, along with an initial test demonstration plate, are each mounted on individual manila hardboard backing sheets. These sheets are cut to size so as to slide easily as a total packet into a wide (1/2") slot contained in the mounting plate. As a result, the topmost plate is progressively exposed through the aperture as the mounting plate is raised at a constant rate by the drive motor. The patient can be tested with any one of the plates by simply removing the plates in front of it in the packet. If the test is performed in the conventional sequence, the plates need only to be removed in succession as they are used. The entire packet is then replaced for the next test.

In operation, the patient is positioned in the head-chin rest, and looks down the housing toward the aperture plate. Beginning with the demonstration plate, the patient operates the motor control switch to progressively raise the plate at a constant rate while viewing that portion which is visible through the aperture. The patient releases the switch at the moment that a cycle change in the plate is noted. The tester then records the associated point on the reference scale of the plate which corresponds to the aperture position. The mounting plate is then returned to zero position, and the tester removes the top plate which was previously visible to the patient, exposing the plate underneath. The procedure is then repeated until all plates have been presented.

The system described above provides a standardized method for presenting the Arden plates, which eliminates the sources of variability due to manual presentation by different individuals. In addition, it establishes fixed values for rate of plate exposure and ambient illumination level. It also standardizes the viewing distance, and thereby eliminates variation in subtended visual angles at the retina of the contrast cycles presented by the Arden plates themselves. Thus, this system should be capable of enhancing the capability of the Arden test for reflecting contrast sensitivity, and should significantly improve the reproducibility and reliability of patient data.

This instrument is now in use to develop a standardization data base, and to compare Arden test plate results with contrast sensitivity data obtained on the same patients using other measurement systems.

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